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16. Abstracts

Independent remote sensing data were desired for comparison with tests of infrared remote sensors. A dual-gas correlation spectrometer was used to measure sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) simultaneously. Data were gathered in Metropolitan Los Angeles. On July 13, 1971, perimeter measurements were made on the premises and around the Kaiser Steel Plant in Fontana. On July 14, perimeter measurements and direct, stack-exit emission measurements were made off-premises at the Southern California Edison Power Generating Station in Etiwanda. On July 15 and 16, reconnaissance surveys were conducted in the Long Beach-Wilmington area to select an appropriate extended-source site for future work; enroute, regional surveys of these gases were undertaken across the Los Angeles Basin. The work near the steel plant and the natural gas fueled power plant resulted in an equal emphasis on nitrogen dioxide and sulfur dioxide because of the presence of both gases.

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Prepared for:

Environmental Protection Agency
Research Triangle, North Carolina

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By:

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San Francisco, California

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SO_2 AND NO_2 MEASUREMENTS
METROPOLITAN LOS ANGELES, CALIFORNIA
13-16 JULY 1971

INTRODUCTION

Tests of infrared remote sensors produced by the General Dynamics Company were in progress in the Los Angeles Basin in July 1971. Independent remote sensing data were desired for comparison. Environmental Measurements, Inc. was issued a contract to measure sulfur dioxide in the vicinity of a power plant and an extended source of pollutants using a Barringer Correlation Spectrometer.

A Dual-Gas Correlation Spectrometer was used to measure sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) simultaneously. Data were gathered in Metropolitan Los Angeles. On July 13, perimeter measurements were made on the premises and around the Kaiser Steel Plant in Fontana. On July 14, perimeter measurements and direct, stack-exit emission measurements were made off-premises at the Southern California Edison Power Generating Station in Etiwanda. On July 15 and 16, reconnaissance surveys were conducted in the Long Beach-Wilmington area to select an appropriate extended-source site for future work; enroute, regional surveys of these gases were undertaken across the Los Angeles Basin.

Results of this work are reported as Task B of Contract No. 6H-02-0124. The work near the steel plant and the natural gas fueled power plant resulted in an equal emphasis on nitrogen dioxide and sulfur dioxide because of the presence of both gases.

EQUIPMENT AND PROCEDURES

The principal equipment used was the newly-introduced Barringer Research Cospec II™ Dual-Gas Correlation Spectrometer (Model S3060, Figure 1). This portable, remote-sensing instrument is intended for quantitative measurement of SO_2 and NO_2 in an optical path between a suitable source of visible and ultraviolet radiant energy, such as Rayleigh-scattered daylight illumination or a quartz iodide lamp.

FIGURE 1
BARRINGER DUAL-GAS CORRELATION SPECTROMETER
SIGHTED ON ETIWANDA POWER PLANT

The Cospec instrument consists of a telescope to collect light from the distant source, a two-grating spectrometer for dispersion of this incoming light, a disc-shaped multiple-slit mask and an electronics system. The disc "correlator" functions as a high contrast reference spectrum for matching against the incoming absorption spectra and is comprised of rays of circular slits photo-etched in aluminum on quartz. These slit arrays are designed to correlate with, sequentially in a positive and negative sense, the absorption bands of the target gas by rotation of the disc in the exit plane. The light modulations so produced are detected by photomultiplier tubes and processed in the electronics to produce a voltage output which is proportional to the optical depth or burden (parts per million-meters) of the gas cloud under observation. The system automatically compensates for changes in varying source light intensity for each channel.

In this application, the instrument was principally used in an upward-looking (vertical) mode of operation. In such a configuration the analog records, produced on a two-channel strip chart recorder, represented the total burden of gas overhead:

$$\text{ppm-m} = \frac{\text{gram-meters}}{\text{cubic meters}} = \frac{\text{grams}}{\text{square meter}} \text{ (total burden)}$$

A knowledge of the wind velocity enables computation of the total flow of gas over the route. If the total burden

includes the plume of a single stack or an industrial site, this calculation results in total emission rates. It is not necessary to enter the source property. Normally a set of roads is selected which completely encircles the source to be studied. Several perimeter traverses are conducted around the isolated area, and simultaneously wind velocity measurements are made. The mass flow (M) across each of the boundary roads of the source is calculated by:

$$M = L\bar{v}G$$

where M = mass flow (grams/second)
L = length of straight traverse section (meters)
$\bar{v}$ = wind velocity (meters/second)
G = average total burden (grams/square meter)

By adding all of the out-of-the-area rates and subtracting the into-the-area rates, a net rate of average gas production is determined. By repeating the traverse a number of times a statistical sample is obtained which reduces errors due to the finite traverse times and the changes in wind condition.

Without question wind is the dominant variable in measuring emissions.

For a coarse measure of the gas concentration at the exit of a stack, the correlation spectrometer is mounted on a tripod and sighted at the stack exit. In this operation mode it is possible to determine the presence or absence of either gas and to give an approximation of the amount of this gas present.

For this work, the Cospec was mounted in a Volkswagon Microbus together with the two-pen Model 7100 Hewlett Packard Strip Chart Recorder and a Cornell-Dubilier sign-wave inverter to operate the recorder. (The Cospec II Spectrometer can operate on DC or AC; because of the recorder the AC mode was chosen.)

The system is calibrated by placing quartz cells containing known quantities of each gas in the line of sight within the instrument. These calibrations are made periodically and used to quantify the resulting data.

RESULTS, TASK B

PERIMETER EMISSION SURVEYS

A number of perimeter surveys were conducted in and about the major steel manufacturing facility owned by Kaiser Steel Company in Fontana, adjacent to the electricity generation plant at Etiwanda owned by the Southern California Edison Company, and in search of an appropriate extended-source location in the Long Beach area. The principal emphasis was at Fontana and Etiwanda; these data have been digitized, and total burden and mass flow maps were produced by computer for all the data gathered. Sketch maps of the results obtained near Long Beach (Wilmington and Torrance) were produced to show the presence of gas during these surveys.

Wind data and computer calculations of all data are included as an appendix.

13 July 1971 - Fontana, California

The General Dynamics pollution monitoring equipment was focused, from a location north of the plant, on a large single smokestack just inside the boundary of the Kaiser Steel Plant. Arrangements were made with Mr. G. L. Rounds, a research chemist with Kaiser's Environmental Quality Control Department, to measure total burdens directly adjacent to the stack inside the plant boundary. Mr. Rounds was able to direct the EMI

vehicle immediately adjacent to the stack, closer than necessary. A road downwind approximately 75 meters due east was chosen.

The total burden measurements obtained during six separate passes along this route are shown in Figure 2 on a map of travelled routes within the steel plant. For clarity, each traverse has been arbitrarily offset to the east for ease of comparison. The calculated mass flow of these burdens, using wind data obtained from a 40-meter high recording anemometer (located only 100 meters eastward) are plotted in Figure 3. The total emissions calculated from these flows are summed in Table I; the sulfur dioxide was flowing from this stack at an average rate of 3.1 metric tons per day (0.13 metric tons per hour).

TABLE I

Total SO_2 Emissions, Kaiser Stack Source
13 July 1971

Time (PDT)	Emission Rate (Metric Tons/Day)
1430	1.5
1435	4.6
1440	3.1
1445	3.3
1450	3.6
1455	2.4

Average Rate of Flow = 3.1 MT/D

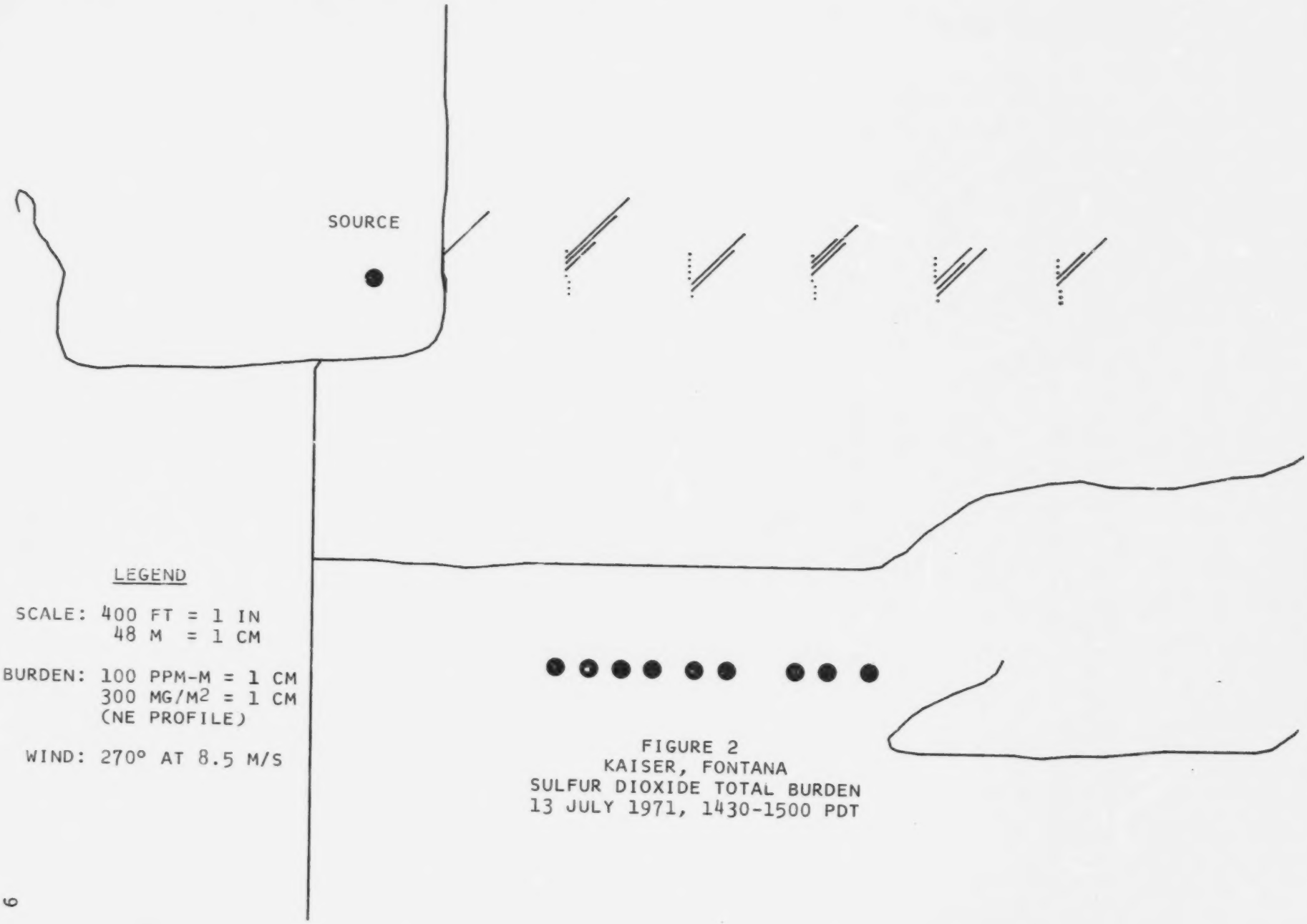


FIGURE 2
KAISER, FONTANA
SULFUR DIOXIDE TOTAL BURDEN
13 JULY 1971, 1430-1500 PDT

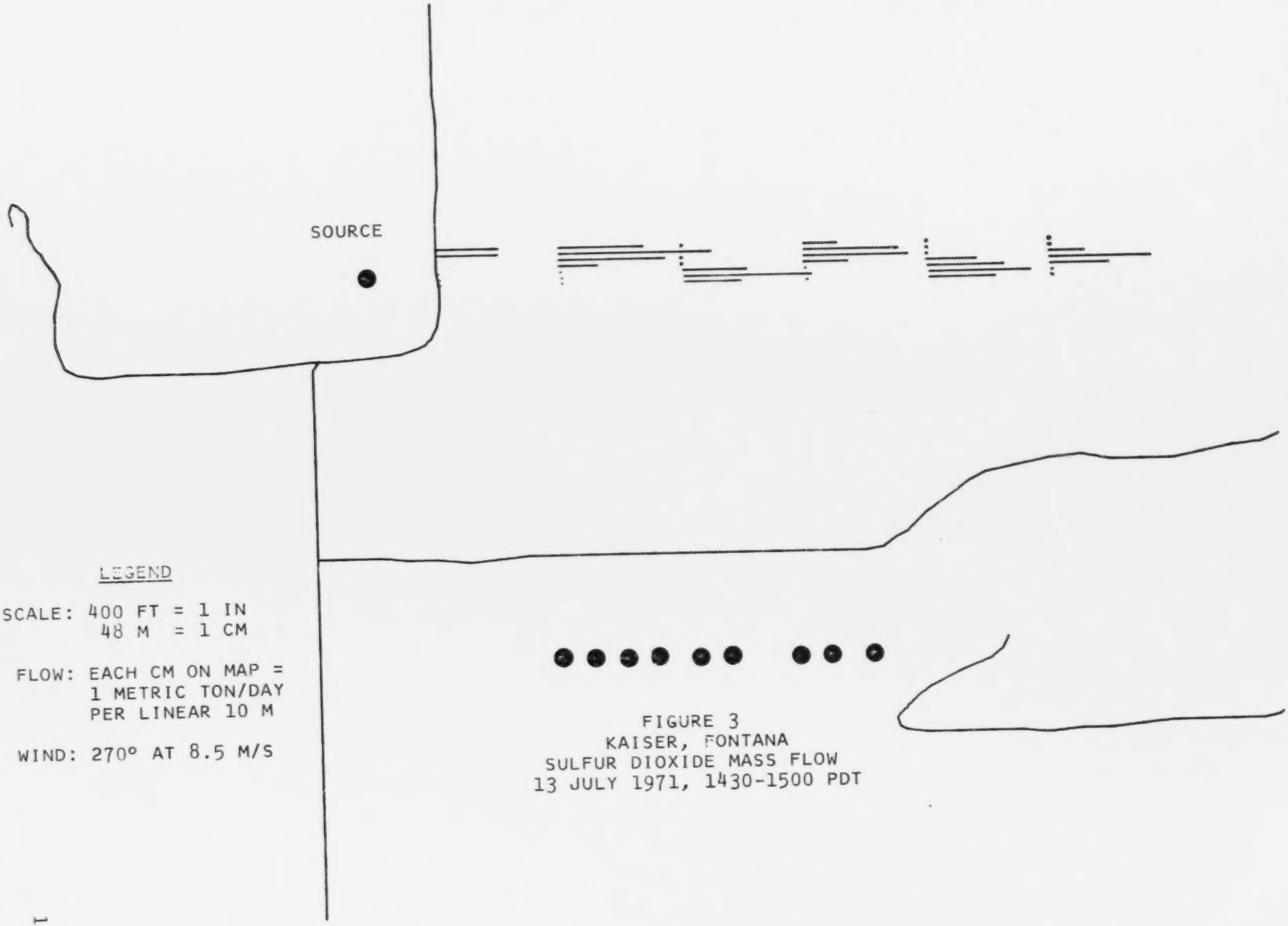


FIGURE 3
KAISER, FONTANA
SULFUR DIOXIDE MASS FLOW
13 JULY 1971, 1430-1500 PDT

On completion of the stack traverses, Mr. Rounds suggested that data downwind of the open-hearth furnaces might show the possible presence of nitrogen dioxide. Figures 4 and 5 show total burden and mass flow for the sulfur dioxide downwind of this facility. Figures 6 and 7 show nitrogen dioxide effluent from this facility. (The scale factor has been increased by five because of the smaller emissions of this gas.) Because of the micrometeorology inherent adjacent to the very hot furnaces, buildings, and the many stacks and billowing plumes, mass flow calculations using a single-direction wind are considered invalid in computing the emissions of this facility -- at this close distance. Nevertheless, these emissions were calculated and approximately 13.5 metric tons per day of SO_2 and 4.8 MT/D of NO_2 were noted along the roadway closest to the hearth, and 13.5 MT/D of SO_2 and 12.0 MT/D of NO_2 were located about 200 meters distant. These must be considered very coarse approximations, but the build-up of NO_2 is noteworthy.

14 July 1971 - Etiwanda, California

On 14 July, the General Dynamics crew focused on the smokestacks at the Southern California Edison power generation station at Etiwanda. EMI conducted a large number of traverses on Etiwanda Avenue and Arrow Road downwind of the plumes but off-premises of the power station. Both sulfur dioxide and nitrogen dioxide were measured. Figure 8 shows the morning

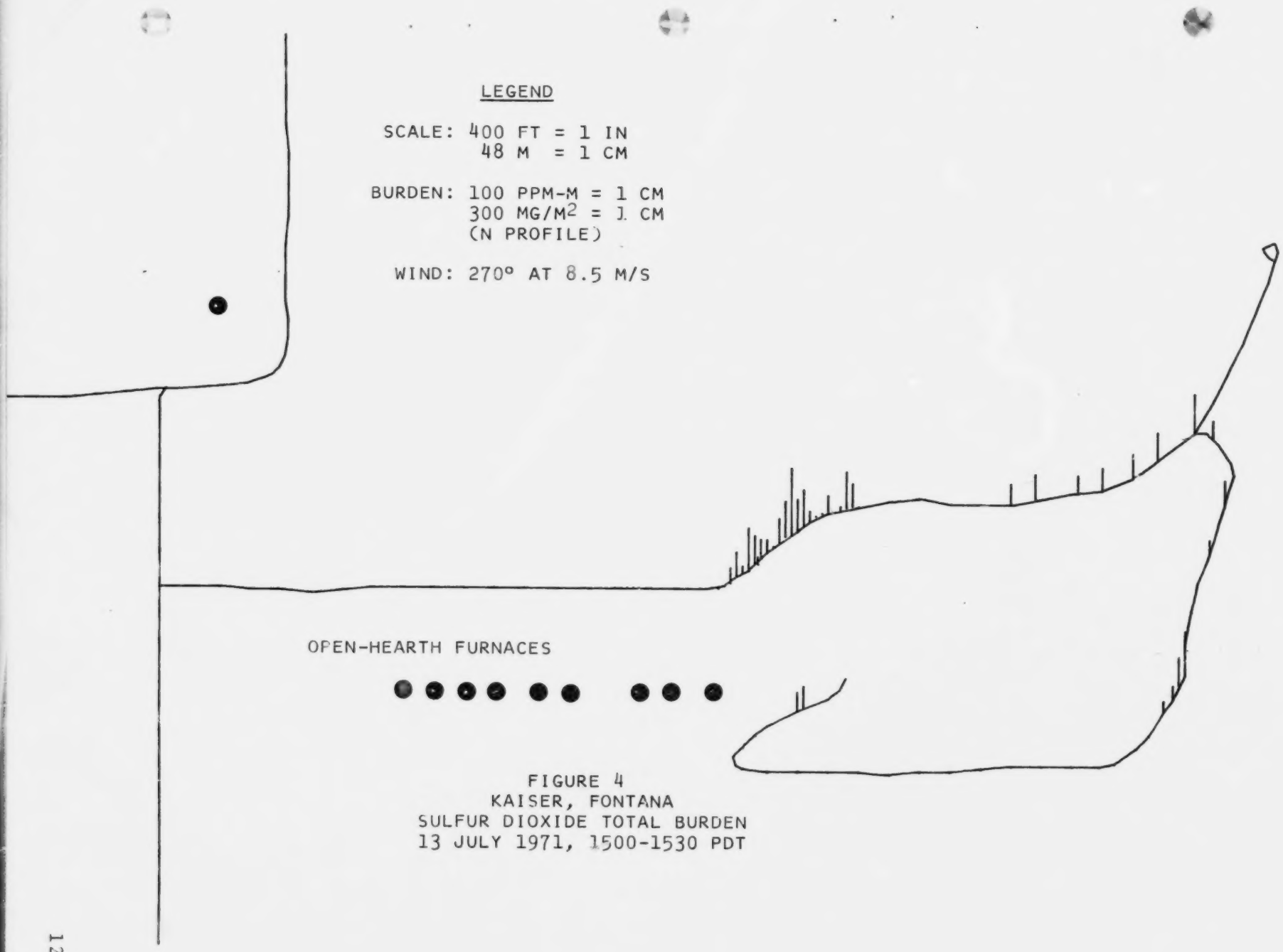


FIGURE 4
KAISER, FONTANA
SULFUR DIOXIDE TOTAL BURDEN
13 JULY 1971, 1500-1530 PDT

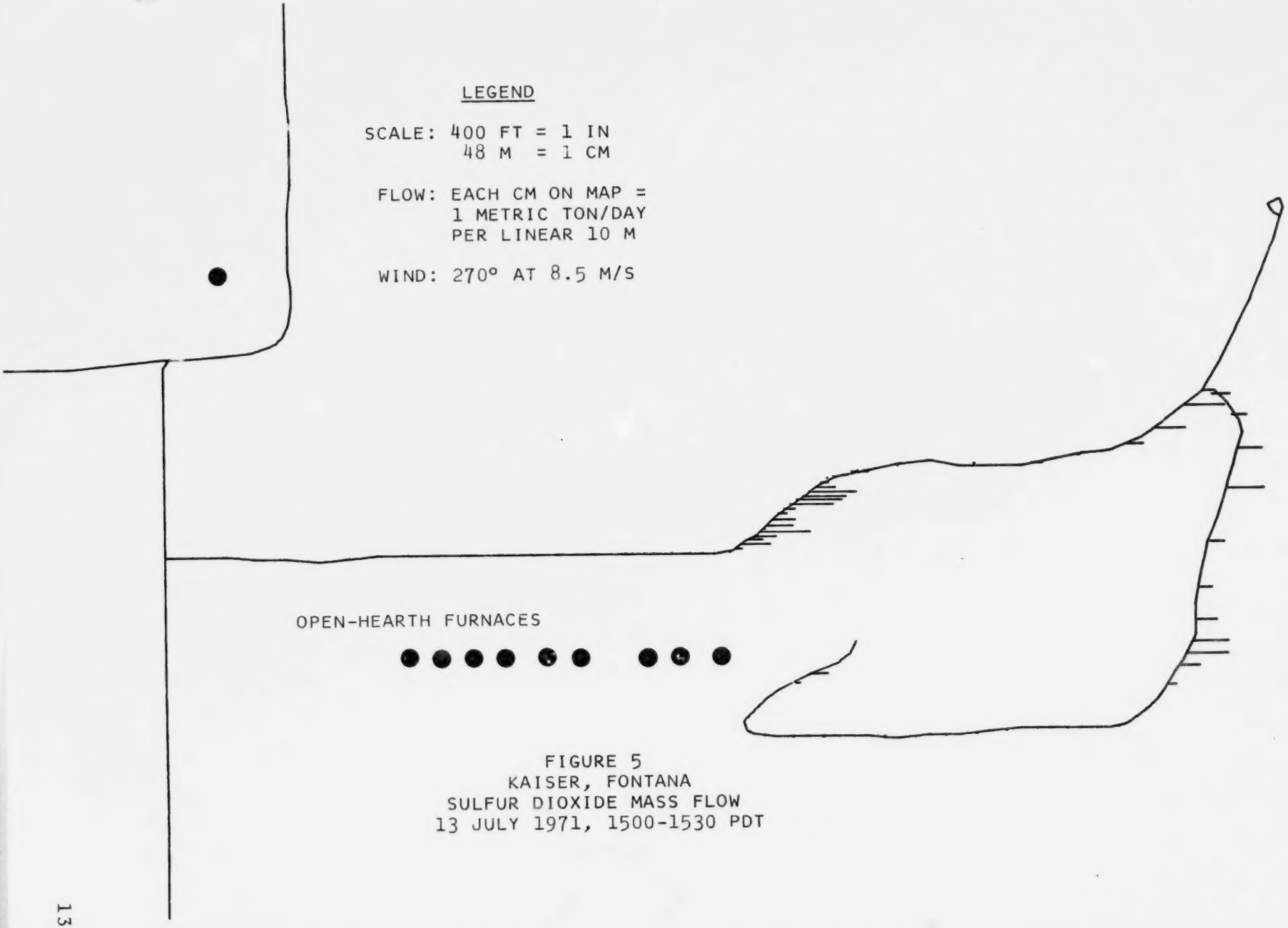


FIGURE 5
KAISER, FONTANA
SULFUR DIOXIDE MASS FLOW
13 JULY 1971, 1500-1530 PDT

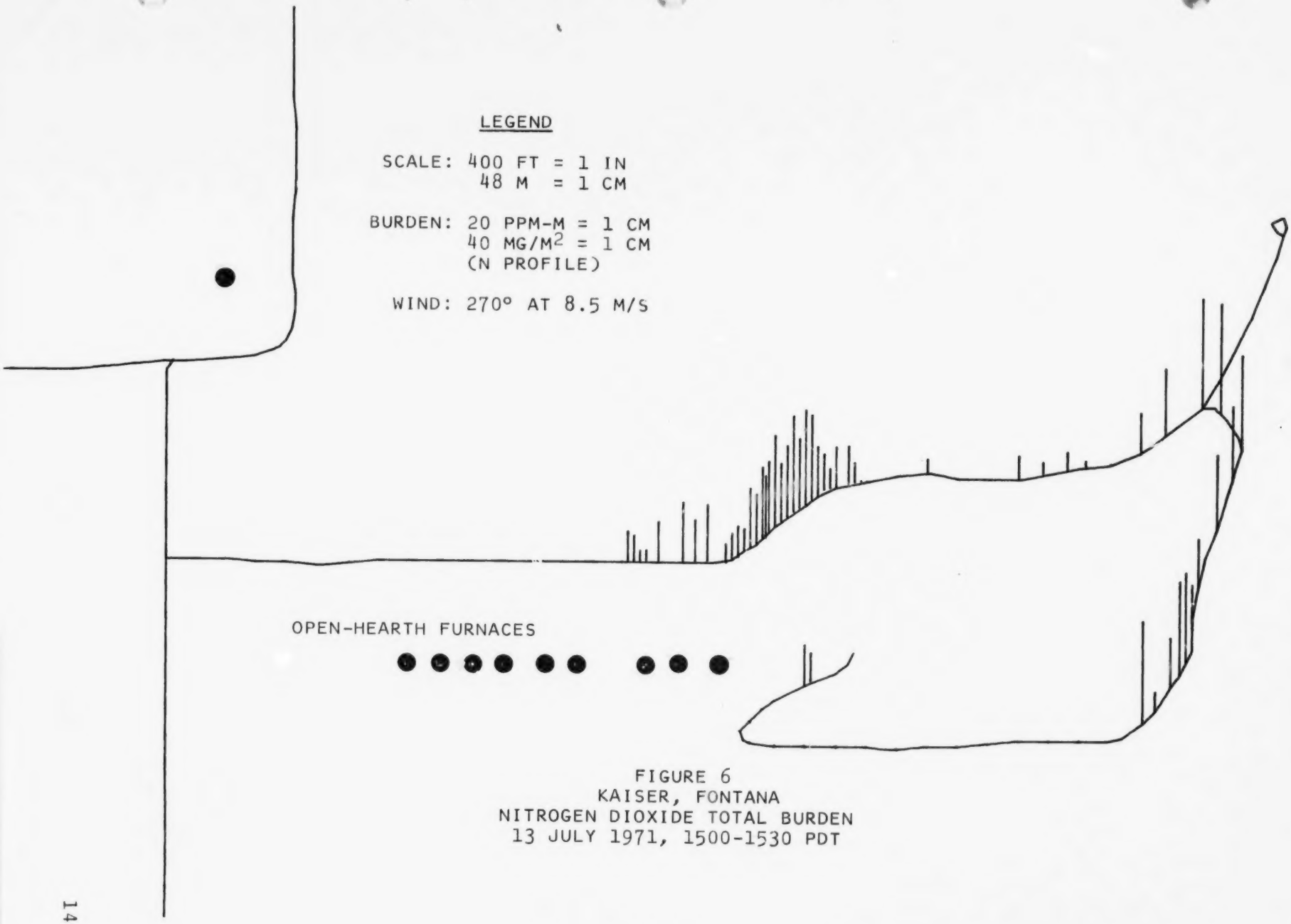


FIGURE 6
KAISER, FONTANA
NITROGEN DIOXIDE TOTAL BURDEN
13 JULY 1971, 1500-1530 PDT

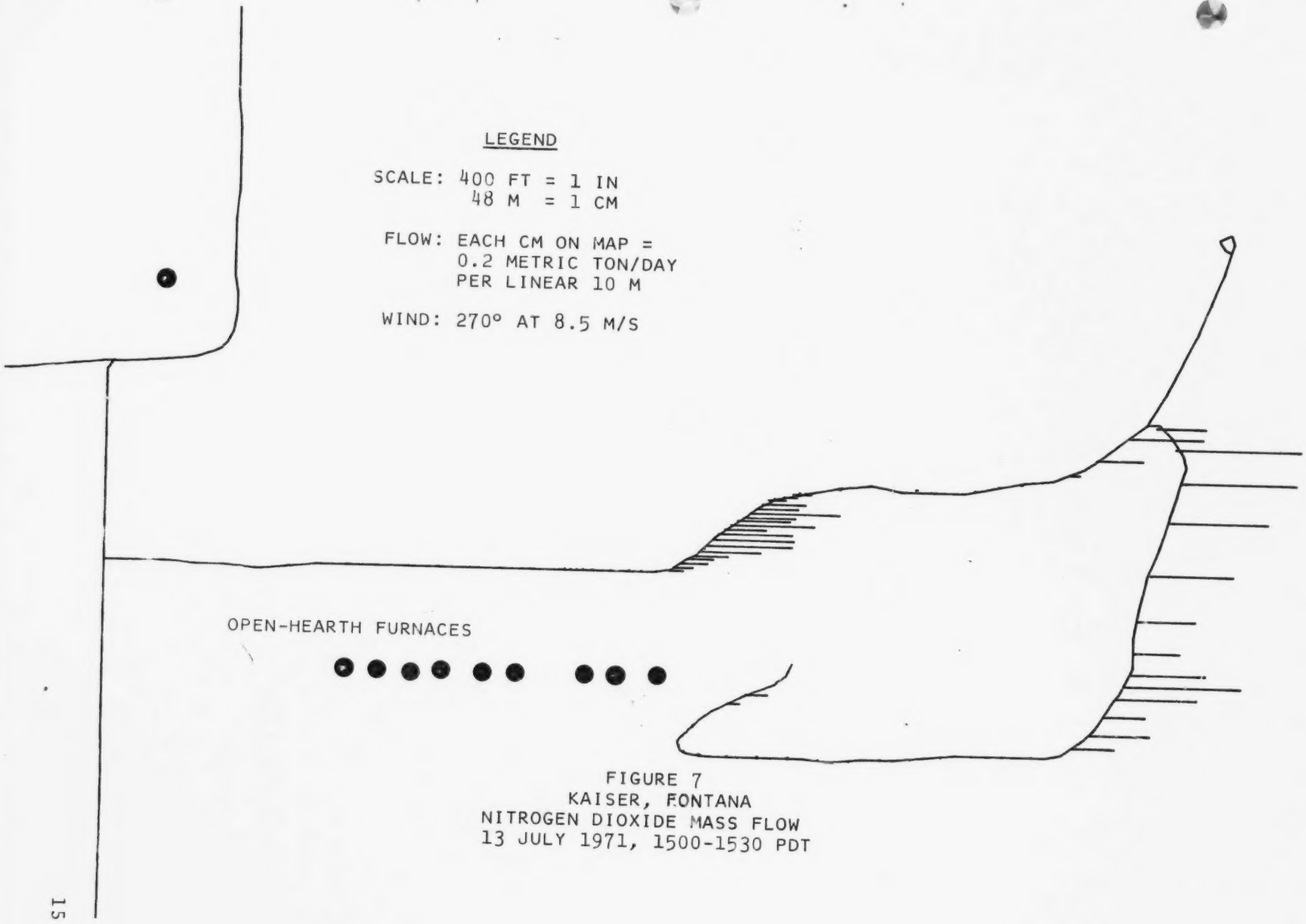


FIGURE 7
KAISER, FONTANA
NITROGEN DIOXIDE MASS FLOW
13 JULY 1971, 1500-1530 PDT

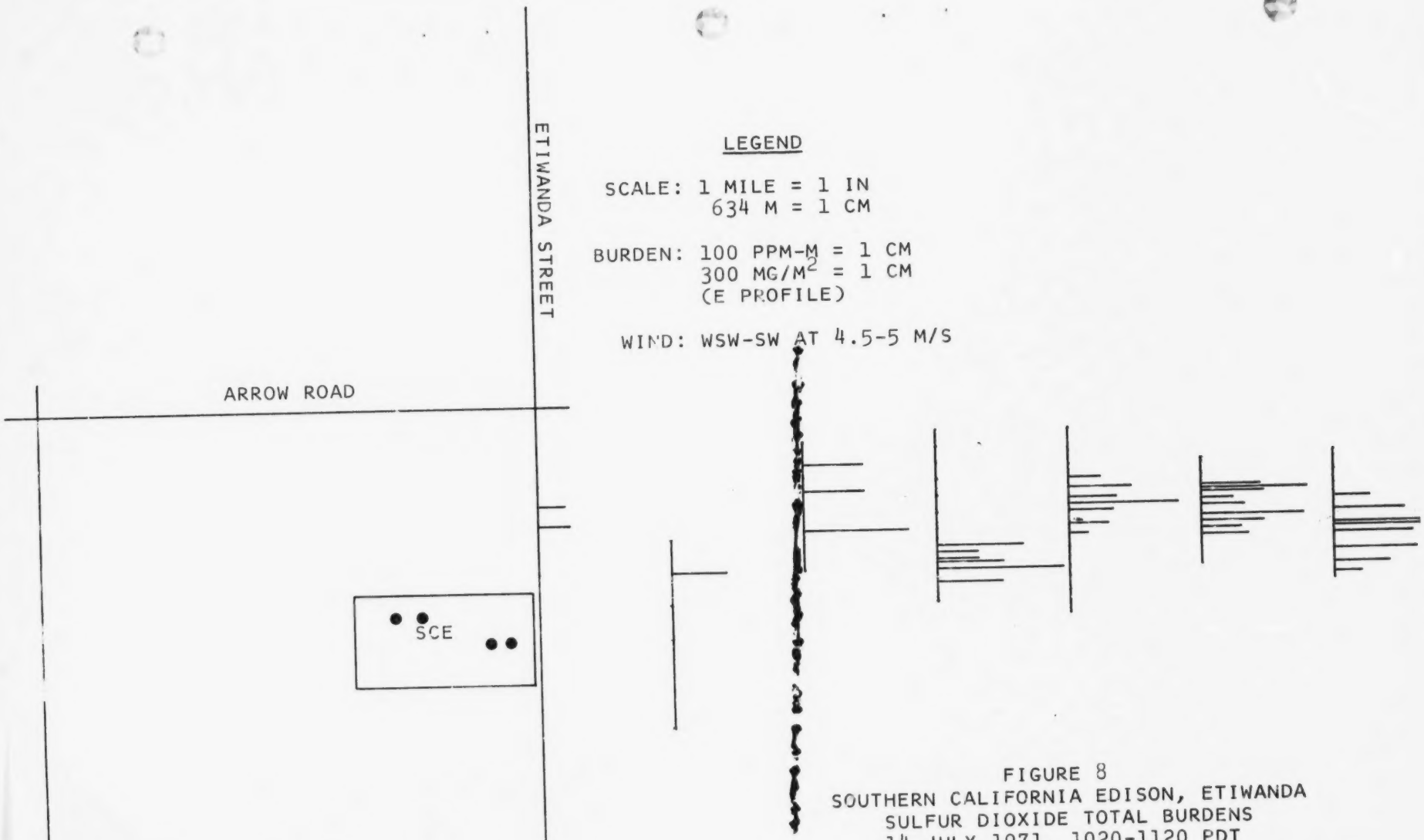


FIGURE 8
SOUTHERN CALIFORNIA EDISON, ETIWANDA
SULFUR DIOXIDE TOTAL BURDENS
14 JULY 1971, 1020-1120 PDT

burdens for sulfur dioxide downwind of Etiwanda, again offset for clarity. Figure 9 shows the nitrogen dioxide burdens. SO_2 and NO_2 afternoon burdens are on Figures 10 and 11, respectively. Mass flow calculations are listed in Table II; maps were not produced because the wind data were not initially available. (A scan of the appended calculations will show an arbitrary one meter per second wind; the results were subsequently multiplied by actual wind to produce the table.)

TABLE II

Total SO_2 & NO_2 Emissions, Etiwanda Power Plant
14 July 1971

Time (PST)	NO_2 (Metric Tons per Day)	SO_2 (Metric Tons per Day)
1020	9.8	12.5
1025	9.4	15.6
1030	7.9	41.7
1105	10.3	32.2
1110	8.0	22.8
1115	10.3	29.5
1120	12.6	46.0
1330	12.9	44.3
1345	10.5	54.7
1350	6.4	13.6
1422	5.6	18.5
Average Rate of Flow	9.4	30.1

An average 9.4 MT/D of NO_2 and 30.1 MT/D of SO_2 were put forth. It appears that fuel content and/or power load changed from 1030 to 1345 hours because the emissions for both NO_2 and SO_2 increased during this midday period. The scatter for SO_2 data are to some extent the result of

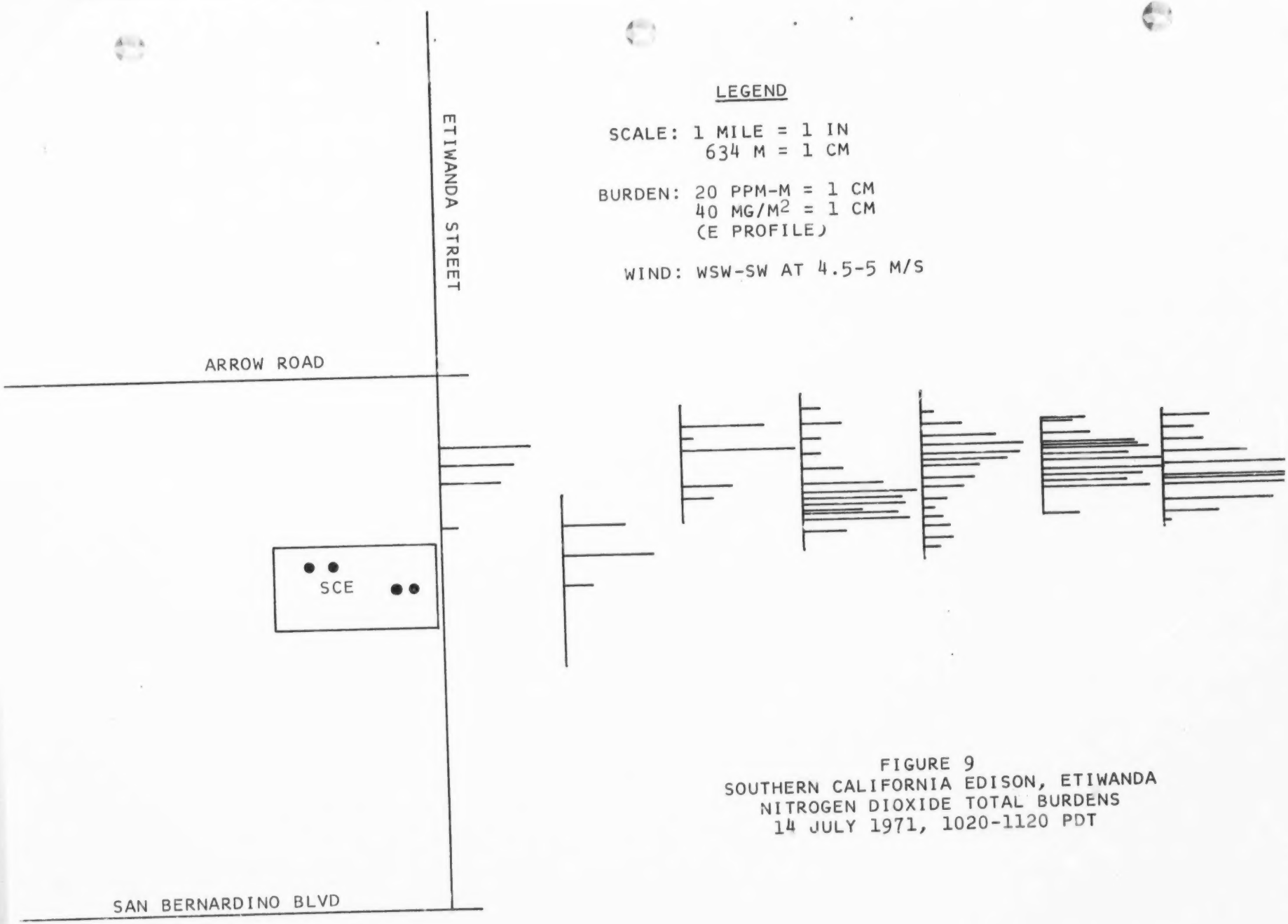


FIGURE 9
SOUTHERN CALIFORNIA EDISON, ETIWANDA
NITROGEN DIOXIDE TOTAL BURDENS
14 JULY 1971, 1020-1120 PDT

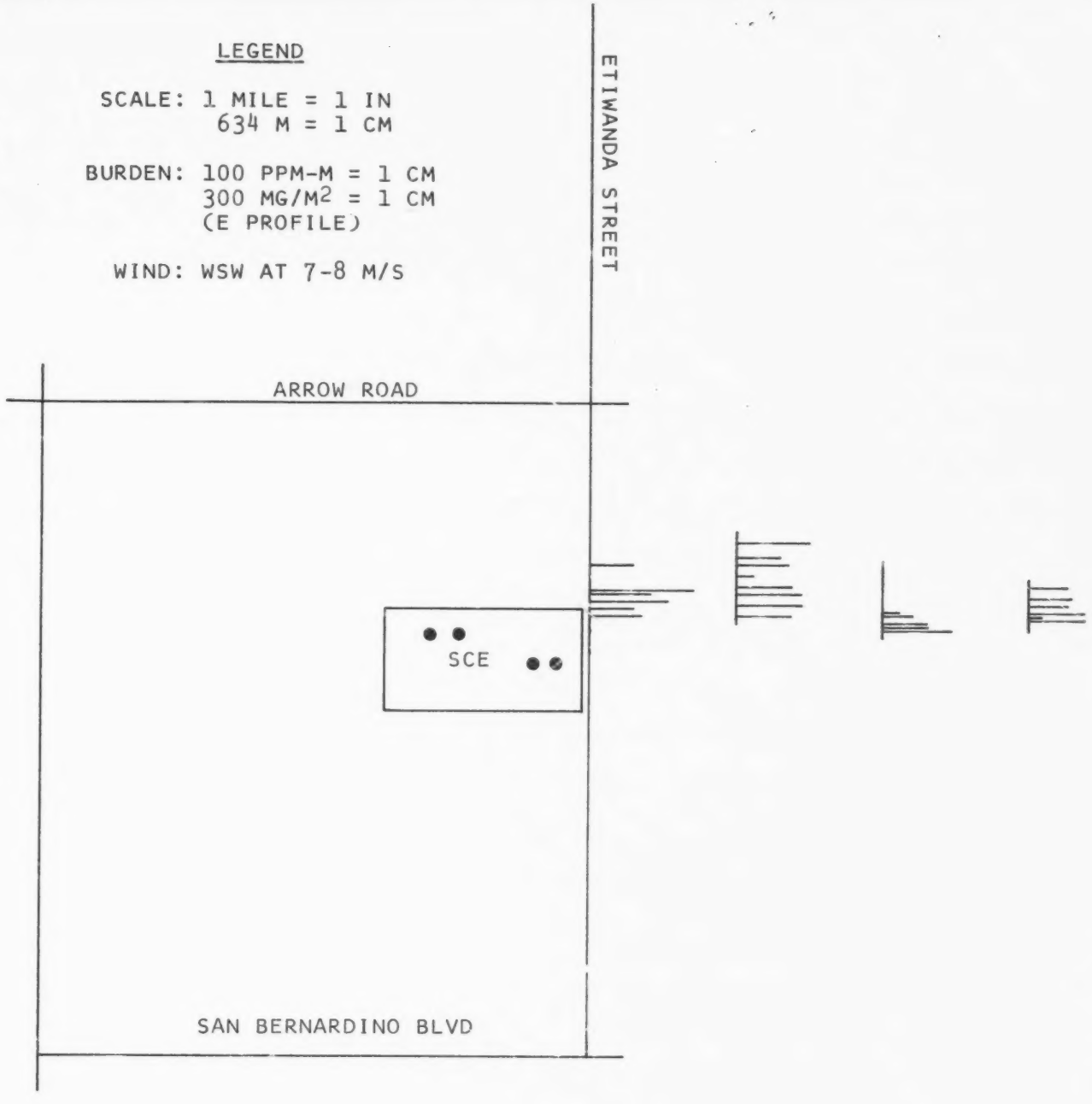


FIGURE 10
SOUTHERN CALIFORNIA EDISON, ETIWANDA
SULFUR DIOXIDE TOTAL BURDENS
14 JULY 1971, 1330-1430 PDT

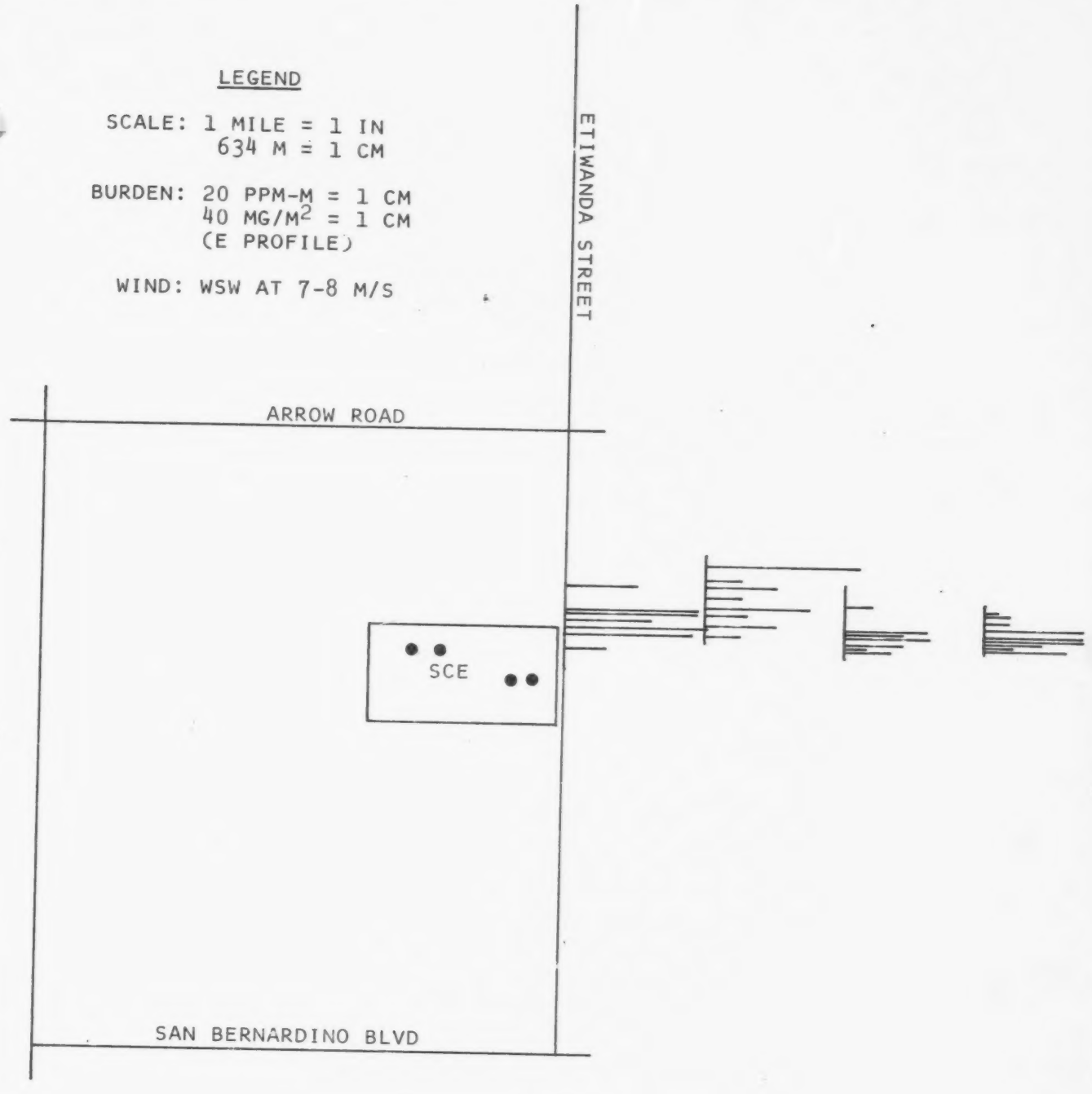


FIGURE 11
SOUTHERN CALIFORNIA EDISON, ETIWANDA
NITROGEN DIOXIDE TOTAL BURDENS
14 JULY 1971, 1330-1430 PDT

non-optimum tuning of this channel (see Calibration Section), but the average readings are valid and consistent.

14 July 1971 - Fontana/Etiwanda, California

During the afternoon a traverse was driven around both the Southern California Edison and Kaiser facilities. The route was travelled clockwise along Arrow Road to Citrus, to San Bernardino, to Cherry, returning to Etiwanda, along Whitram. A sketch of the nitrogen dioxide total burden, Figure 12, clearly shows the separation of two distinct plumes. The total burden is shown plotted to the northwest, and the approximate boundaries of the plumes are shaded.

These data are not digitized, but a distinct increase in nitrogen dioxide appears evident in this sketch. While NO_2 was present upwind of both facilities, it was present in very much lesser amounts than created by the plume.

15 July 1971 - Wilmington/Carson, California

On this date the Barringer equipment was used to locate an extended-source site near Long Beach. A number of petroleum refineries and industrial chemical sites were surveyd, and a sketch of the principal sulfur dioxide total burden is shown in Figure 13. Principal SO_2 emissions appear to be coming from a Stauffer Chemical facility southeast of Alameda Street in Carson.

It was striking to note that minimum amounts of SO_2 (or NO_2) appeared downwind of the Atlantic Richfield, Texaco

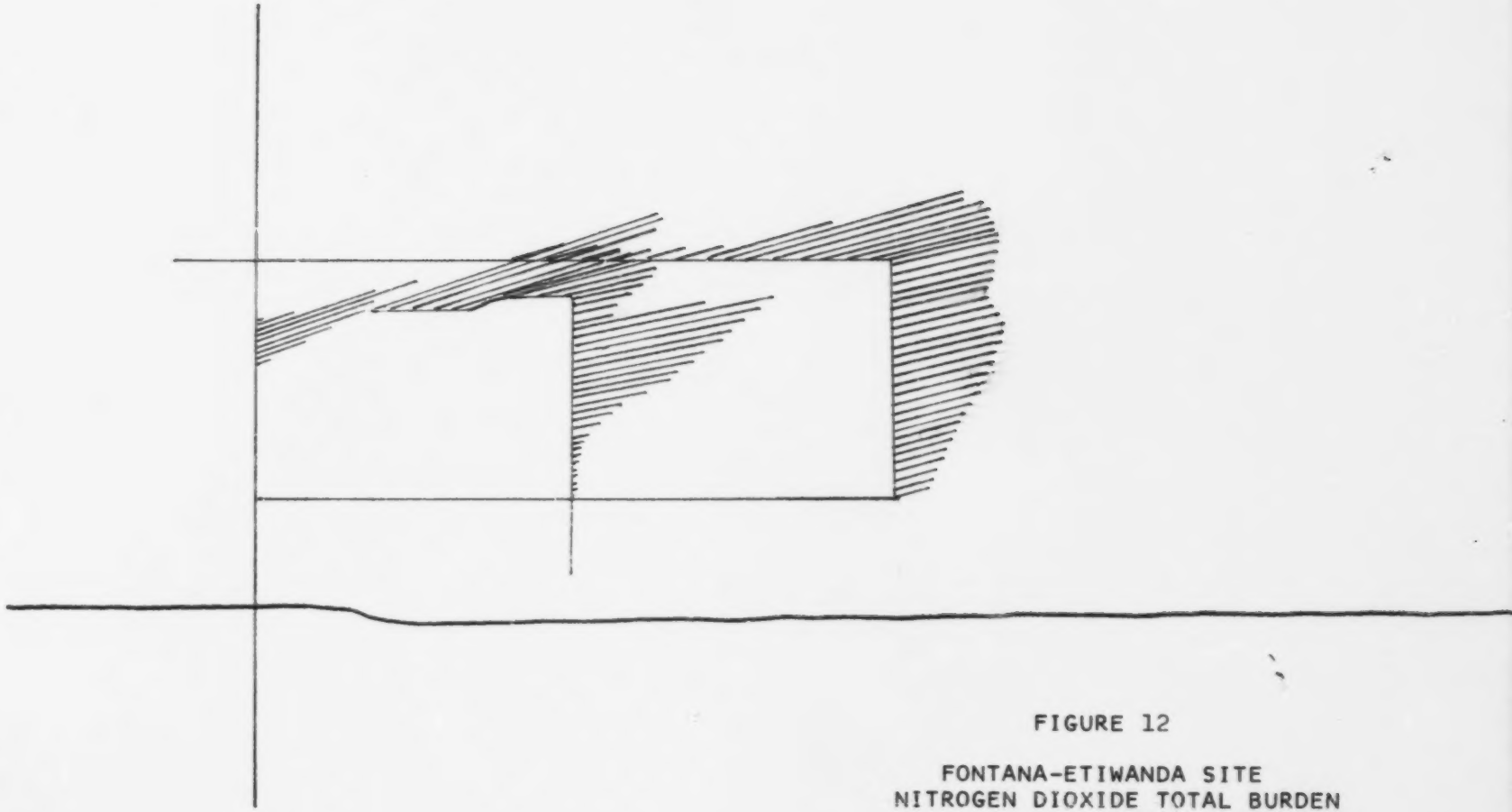
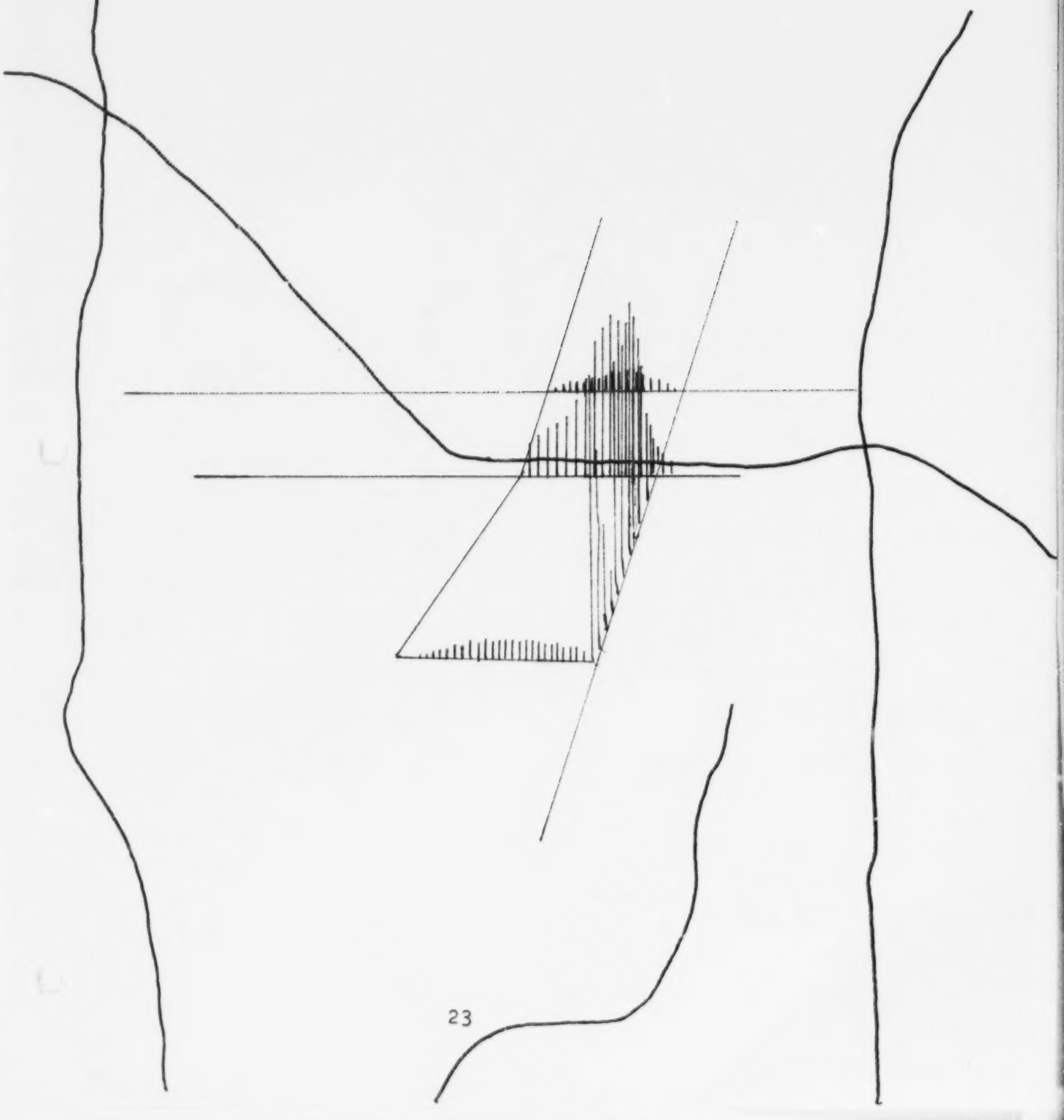


FIGURE 12

FONTANA-ETIWANDA SITE
NITROGEN DIOXIDE TOTAL BURDEN
SKETCHED ALONG FLOW DIRECTION
14 JULY 1971, 1430 PDT

FIGURE 13

WILMINGTON/CARSON, CALIFORNIA
SULFUR DIOXIDE TOTAL BURDEN
15 JULY 1971, AFTERNOON
SKETCHED ALONG FLOW DIRECTION



and Shell refineries in this region. There was some gas present, but it was not what was anticipated.

A sketch of the NO_2 emission is shown in Figure 14.

A site was selected near the Dominguez Hills which would allow a two-mile traverse downwind of the general petrochemical facilities.

STACK MONITORING, ETIWANDA

After the perimeter surveys on July 14, the correlation spectrometer was placed on a tripod to view the stack exits at Etiwanda. Figure 16 shows the two westerly stacks of the generators, about one mile south from the viewing site. Observations were made of these and two additional stacks to the east.

The Cospec instrument was sighted on each stack exit and, downwind of the stack, a vertical "slice" was made from the horizon to high above each stack. Sulfur dioxide was

FIGURE 14

WILMINGTON/CARSON, CALIFORNIA
NITROGEN DIOXIDE TOTAL BURDEN
15 JULY 1971, AFTERNOON
SKETCHED ALONG FLOW DIRECTION

Figure 15, page 26 has been omitted.

FIGURE 16
SOUTHERN CALIFORNIA EDISON, ETIWANDA
MONITORING STACK-MOUTH GAS CONCENTRATIONS WITH THE COSPEC II

measured from the second western-most stack (the left stack in Figure 16). No sulfur dioxide was measured emanating from the other three stacks. Little if any nitrogen dioxide was noted at the stack exit of any of the stacks, though it did appear downwind.

A twenty-minute temporal monitor of sulfur dioxide is shown in Figure 17; to record this, the instrument was left to monitor concentration-pathlength just above and a few meters downwind of the emitting stack. The average value over the twenty-minute period was 275 parts per million-meters.

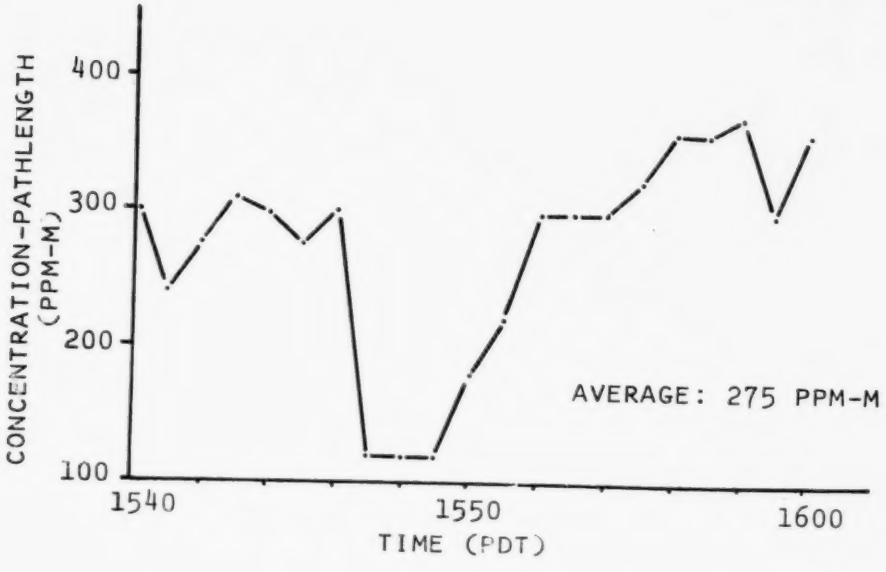


FIGURE 17
SOUTHERN CALIFORNIA EDISON, ETIWANDA
SECOND WESTERN-MOST STACK, STACK EXIT SO_2

The sighting telescope on the Cospec instrument had not been aligned for this distance so the exact stack exit probably was not observed. The 275 ppm-m average value was likely not observed at the stack exit. Therefore, it is not accurate to divide by the exit diameter (and make a thermal correction).

Figure 18 is a plot of true concentration at the specific stack exit versus exit temperature for various possible stack widths. The family of curves is drawn on the basis of the actual field measurement as a function of the temperature correction. By selecting the stack exit diameter, the corrected gas concentration at the stack exit is read-off the curve at the appropriate exit temperature. These curves are included to demonstrate the method, not to claim accuracy in the demonstration results.

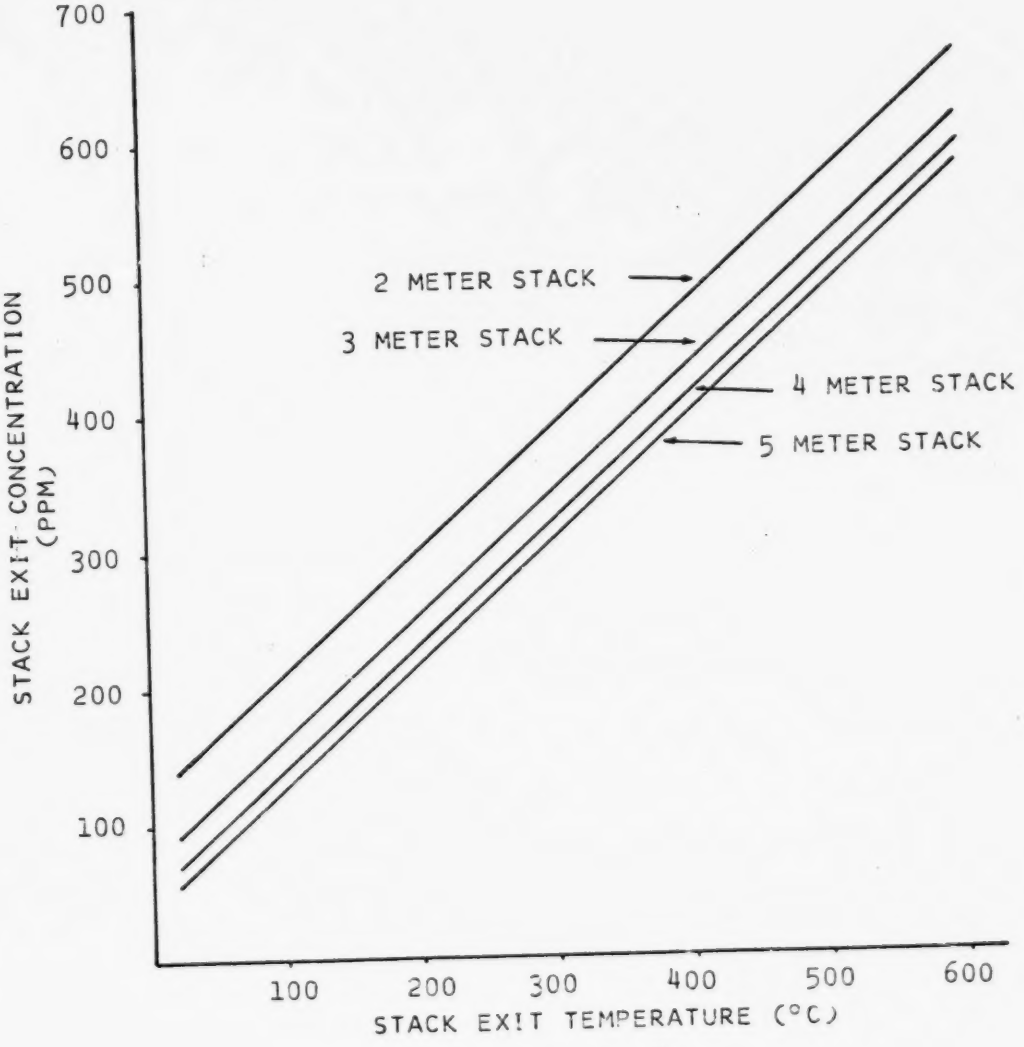


FIGURE 18
SOUTHERN CALIFORNIA EDISON, ETIWANDA
SECOND WESTERN-MOST STACK CONCENTRATION

REGIONAL SURVEYS

Enroute from the principal site of operations in San Bernardino County to Long Beach, two regional surveys were conducted on the freeways of the Los Angeles Basin. Vertical burdens were gathered, at highway speeds, during late morning; principally nitrogen dioxide data was detected. though some sulfur dioxide was noted in the Los Angeles Basin.

15 July 1971 - Ontario/Burbank/Long Beach

It was necessary to divert to Burbank for technical supplies so a route was selected along Interstate 10, to the Hollywood Freeway (US 101), through the San Fernando Valley, to Interstate 405 (the San Diego Freeway).

A significant amount of nitrogen dioxide was noted in the Los Angeles Basin and is shown in Figure 19. This gas virtually disappeared and visibility increased to about ten miles in the San Fernando Valley. The gas cloud was again intersected south of Sepulveda Canyon, and a route along the Interstate 10 (Santa Monica Freeway) and the Long Beach Freeway again intersected the principal NO_2 cloud. When Long Beach was reached, the dominant sea winds produced clean air again.

No attempts were made to relate these total burden data to mass flow because of the distance covered and the significant topography traversed.

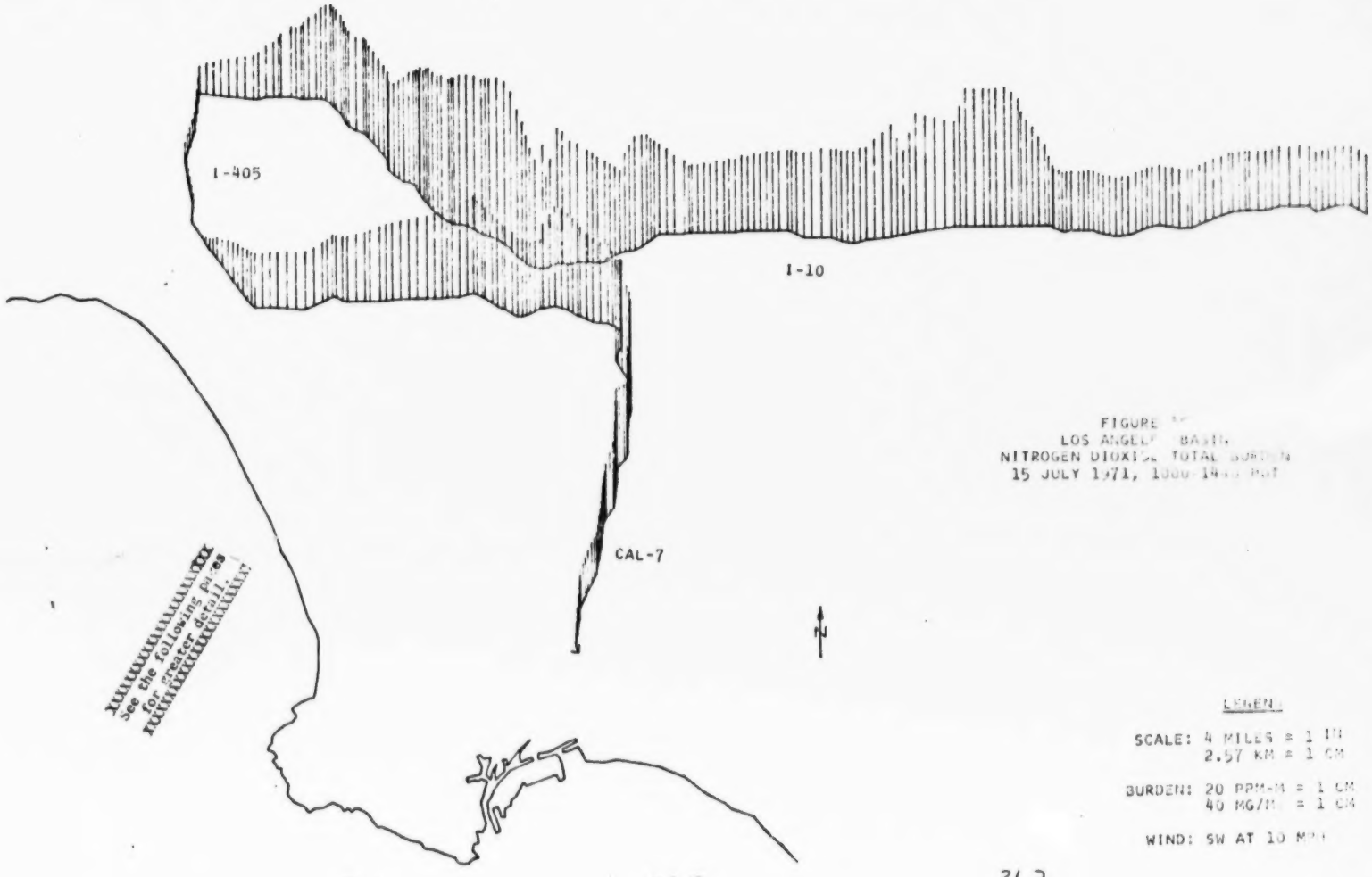


FIGURE [illegible]
LOS ANGELES BASIN
NITROGEN DIOXIDE TOTAL BURDEN
15 JULY 1971, 1000-1400 PST

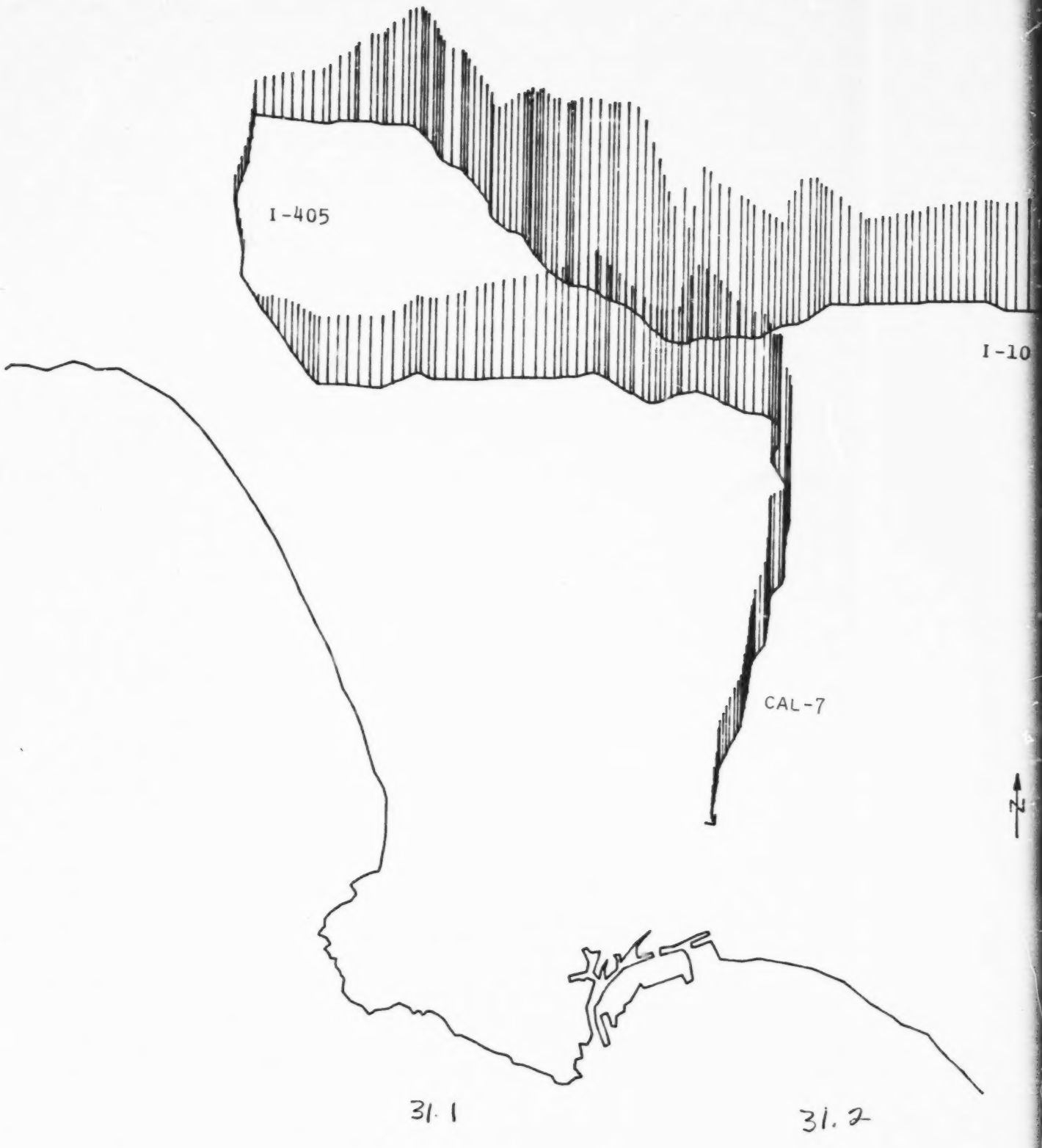
LEGEN

SCALE: 4 MILES = 1 IN
2.57 KM = 1 CM

BURDEN: 20 PPM-M = 1 CM
40 MG/M² = 1 CM

WIND: SW AT 10 MPH

31.1 31.2 31.3


I-405
I-10
CAL-7
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31.1
31.2

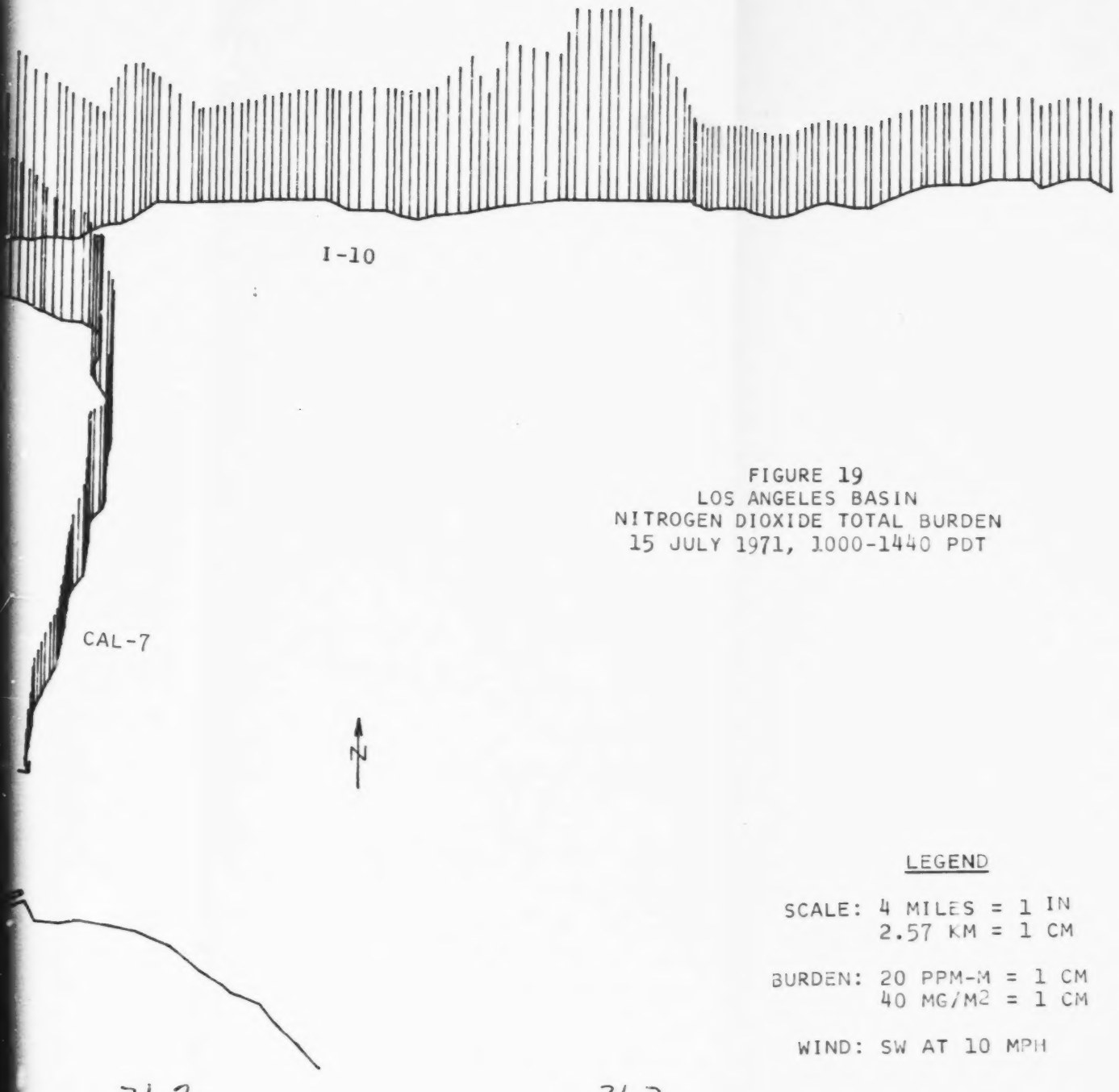


FIGURE 19
LOS ANGELES BASIN
NITROGEN DIOXIDE TOTAL BURDEN
15 JULY 1971, 1000-1440 PDT

LEGEND

SCALE: 4 MILES = 1 IN
2.57 KM = 1 CM

BURDEN: 20 PPM-M = 1 CM
40 MG/M^2 = 1 CM

WIND: SW AT 10 MPH

31.2

31.3

16 July 1971 - Pomona/Long Beach

On the following day, a traverse was made along the Pomona Freeway, encircling downtown Los Angeles, down to Long Beach. The results of this day are shown on Figure 20.

CALIBRATIONS

The Dual-Gas Correlation Spectrometer is easily calibrated by inserting centimeter-thick quartz cells in the optical path. Thus, three points of calibration for each gas are available (two cells plus their combination). For sulfur dioxide the cell values are 78 and 412 parts per million-meters; for nitrogen dioxide, the values are 61 and 166 parts per million-meters.

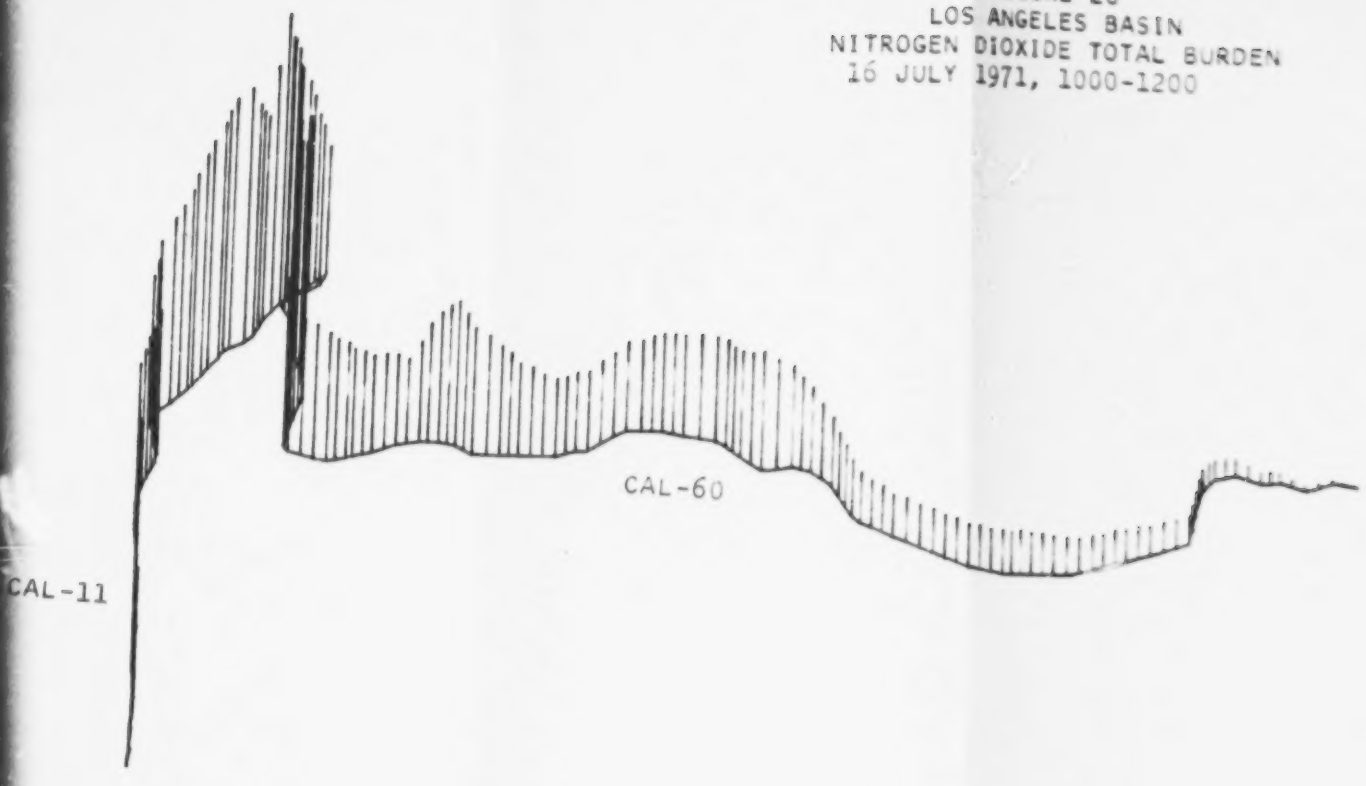
A record of the calibration values was kept during the course of the tests. In each case the low value, high value, and combination cells were placed in the optical path and the average millivolt signal was measured for several seconds or more. Table 3 is a list of the calibrations noted in ppm-m per millivolt.

NO_2

The nitrogen dioxide channel operated excellently during the entire test. The deviation in average value throughout the tests was minor, and the 0.32 ppm-m per millivolt appeared to be a reliable value for data reduction. NO_2 measurements were feasible from sunup to sundown.

CAL-60
CAL-11
N

FIGURE 20
LOS ANGELES BASIN
NITROGEN DIOXIDE TOTAL BURDEN
16 JULY 1971, 1000-1200



LEGEND

SCALE: 4 MILES = 1 IN
2.57 KM = 1 CM

BURDEN: 20 PPM-M = 1 CM
40 MG/M^2 = 1 CM

WIND: SW AT 9 MPH

TABLE III

NO_2/SO_2 Calibrations
(ppm-m per millivolt)

Date	Hour	NO_2	SO_2
13th	1030		2.07
	1110		1.67
	1138	0.31	1.53
	1225	0.29	1.69
	1257	0.32	1.56
	1452	0.31	1.42
	1600	0.31	2.25
	1630	0.31	1.20
13th Average		0.31	1.67
14th	1004	0.33	1.56
	1125	0.33	1.92
	1314	0.32	1.73
	1332	0.31	1.62
	1430	0.37	
	1439	0.31	1.56
	1457	0.31	1.56
	1500	0.31	1.75
	1540	0.34	1.29
	1607	0.35	1.11
14th Average		0.33	1.57
15th	0950	0.34	2.02
	1105	0.32	1.66
	1245	0.31	1.51
	1338	0.31	1.31
	1445	0.32	1.20
	1530		1.72
15th Average		0.32	1.57
16th	0953	0.35	1.58
	1325	0.32	1.32
	1503	0.33	1.44
16th Average		0.33	1.45
4 DAY AVERAGE		0.32	1.59

Common Full Scale Values	NO_2 ppm-m	NO_2 mg/M^2	SO_2 ppm-m	SO_2 mg/M^2
1 volt	320	640	1590	4800
500 mv	160	320	800	2400

SO_2

SO_2 values were 1.59 ppm-m per millivolt ± 30 percent. The reason for this broader range is two-fold: 1) Some calibration values were included before adequate ultraviolet light was available in the morning or after it had set in the afternoon. These values tend to create less sensitive readings. 2) More importantly perhaps is that the SO_2 channel was tuned to a less-sensitive-than-optium position. This fact did not reduce the validity of the SO_2 data, but they were more noisy than they should have been. The repeatability of the calibration, and the "real-time" calibration procedures, confirm the data. Nevertheless, a set-screw had vibrated loose during shipment; this allowed the grating to shift to a less-sensitive position. After these tests this was noted, and a sensitivity of 0.41 ppm-m per millivolt was obtained for the SO_2 channel.

CONCLUSION

Measurable amounts of sulfur dioxide and nitrogen dioxide were present downwind of the two principal sources under study in Task B. The dispersal pattern of the nitrogen dioxide plume was traced for four miles.

Relatively small amounts of sulfur dioxide were noted emanating from the Kaiser and one Etiwanda Power Plant stack.

Noteworthy was the presence of nitrogen dioxide very close to the stationary stack sources. This reactive air pollutant appeared only a few tens of meters downwind of the source. One possible explanation might be the presence of large amounts of ozone in the atmosphere causing an immediate chemical change in the effluent of nitrogen oxide.

The correlation spectrometer was used to seek out an extended source for future work on this task. Virtually all industrial facilities in the metropolitan Long Beach area were rapidly evaluated using perimeter traverse techniques.

Enroute between sites, regional air pollution maps were produced across the Los Angeles Basin. These maps give a relative basis to the source measurements, which were the principal purpose of the test.